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(54) LAMP FOR LASER APPLICATIONS

(57) The invention relates to a lamp for use in laser applications. The lamp (1) has a laser (3) adapted for emitting optical radiation along an optical path and a transparent body (5) comprising a fluorescent body (4). The transparent body (5) is arranged in the optical path, and the fluorescent body (4) has a shape that is elongated in a predetermined direction. The lamp (1) further has a collecting unit (8) for transmitting at least a portion of optical radiation emitted by the fluorescent body (4) to an output of the lamp (1). In this way, a small spot and little divergence is provided in conjunction with good heat dissipation leading to a high optical performance.

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Description

FIELD OF THE INVENTION

[0001] The invention relates to a lamp for use in laser applications, such as high-power laser applications and/or lighting applications.

BACKGROUND OF THE INVENTION

[0002] US 7,165,871 B2 describes a lamp for generating light which comprises a semiconductor light emitting element for emitting light, a fluorescent material, provided away from the semiconductor light emitting element, a first optical member operable to focus the light generated by the semiconductor light emitting element on the fluorescent material, and a second optical member having an optical center at a position where the fluorescent material is provided, operable to emit light from the fluorescent material based on the light focused by the optical member to an outside of the lamp. The lamp is used as a headlamp in a vehicle, and the second optical member emits the light from the fluorescent material to the outside of the lamp, so that the second optical member forms at least one of a part of a cut line that defines a boundary between a bright region and a dark region of the headlamp. This document further describes the combination of a laser, a phosphor and a reflector integrated into a light emitting module used for automotive front light applications. Such lasers usually deliver pencil-shaped beams originating from a small spot and showing little divergence. Very local heat dissipation in the fluorescent material appears and thus limits the brightness of such a lamp.

[0003] During the last decades, light emitting diodes (LEDs), have become more and more important in lighting applications due to the advances of semiconductor technology. High-power LEDs have opened the door to new lighting concepts comprising miniaturization, lifetime, efficiency and sustainability of the optical elements.

[0004] Lasers show a much higher brightness than LEDs. Semiconductor lasers showing output powers in the range of several Watts are available and thus enable a high lumen output. Currently, laser pumped optical lamps for different potential lighting applications are investigated. It is expected that they show a high potential for dedicated lighting applications such as spots for automotive, architectural indoor, outdoor and accent lighting.

[0005] However, there is a need to utilize the strong quality of lasers comprising their high brightness and keeping their optical performance as high as possible in conjunction with solving the above-mentioned thermal issue problem.

SUMMARY OF THE INVENTION

[0006] It is an object of the invention to improve optical performance in laser applications in conjunction with solving the thermal issue problem mentioned above in order to mitigate heat accumulation in a fluorescent body and thus to improve heat transport through a transparent body which comprises the fluorescent body.

[0007] This object is achieved by a lamp comprising a laser adapted for emitting optical radiation along an optical path and a transparent body arranged in the optical path and comprising a fluorescent body, wherein at least one of the transparent body and the fluorescent body has a shape that is elongated in a predetermined direction. Each of the transparent body and the fluorescent body may have a shape that is elongated in the same predetermined direction. The lamp further comprises a collecting unit which is adapted for transmitting at least a portion of optical radiation emitted by the fluorescent body to an output of the lamp. The transparent body has a thermal conductivity that is equal to or larger than 10 W/mK.

[0008] It is an important idea of the invention that it becomes possible to improve heat transport through the transparent body.

[0009] According to a preferred embodiment of the invention, the transparent body is a holder that is attached to the fluorescent body or arranged close to it and thus close to the hotspot. The holder may have a shape that is elongated in a predetermined direction which is equal to the predetermined direction of the elongated shape of the fluorescent body.

[0010] The collecting unit may comprise an optical center arranged in the transparent body.

[0011] The lamp may further comprise a focusing unit which is adapted for focusing the optical radiation emitted from the laser onto at least a part of the fluorescent body.

[0012] The lamp may comprise at least two lasers, each emitting optical radiation which is combined.

[0013] The lamp may further comprise a heat-spreader provided at the transparent body, wherein the heat-spreader is adapted for conducting heat irradiated from the fluorescent body to a sink.

[0014] The transparent body may have an optical transmission equal to or more than 80 %, preferably equal to or more than 90 %, more preferably of equal to or more than 95 %.

[0015] The transparent body has a thermal conductivity that is equal to or more than 10 W/mK. Preferably, the thermal conductivity of the transparent body is equal to or more than 40 W/mK, more preferably equal to or more than 100 W/mK.

[0016] When the transparent body is a holder, the holder may have a wall thickness equal to or more than 0.5 millimeter and/or equal to or less than 10 millimeters.

[0017] The transparent body may comprise a material chosen from the group consisting of diamond, sapphire, and a ceramic material.

[0018] The transparent body may have a shape that corresponds to a rod, a fiber, a wire and/or a cylinder. Other shapes may be a spherical shape, an aspherical shape, a Fresnel-shape, a diffractive shape, e.g. a periodic structure, or a non-periodic structured shape. Also, a combination these shapes is possible.

[0019] If the transparent body has the shape of a rod, the rod may have a diameter equal to or more than 1 millimeter and/or equal to or less than 10 millimeters. The rod may have a length equal to or more than 0.3 millimeter and/or equal to or less than 100 millimeters. The rod may correspond to a thin elongated Lumiramic material, the term "Lumiramic" describing a phosphor technique of the applicant and being related to a material combination of a ceramic and a phosphor. The Lumiramic material is preferably encapsulated by a transparent heat-spreader.

[0020] The transparent body may comprise the entire space within the collecting unit.

[0021] The fluorescent body may comprise a fluorescent material that comprises a predetermined diameter and a length of equal to or more than 3 times the predetermined diameter, preferably equal to or more than 5 times the predetermined diameter, and more preferably equal to or more than 10 times the predetermined diameter. The fluorescent material may be a Lumiramic material.

[0022] The laser may be adapted for exciting fluorescent emission over a predefined length of the fluorescent material comprised by the fluorescent body. In this way different beam shapes can be realized. The laser may be adapted for tuning the optical radiation emitted along the optical path. The laser may be a semiconductor laser, a solid-state laser, or a fiber laser.

[0023] The invention provides a lamp adapted for generating light. The lamp has a source that comprises a laser. A fluorescent body is substantially embedded in a transparent body and is provided away from the source, such that the lamp shows a high optical performance. The lamp may have a focusing unit that is adapted for focusing light or optical radiation generated by the source onto the fluorescent body. The focusing unit may be adapted for focusing light or optical radiation generated by the source through the transparent body. The transparent body and the fluorescent body substantially embedded therein have a good thermal interface corresponding to a low thermal contact resistance. The transparent body may be a holder, and attachment between the holder and the fluorescent body may be achieved by melting glass, ceramic glue, or by transparent pressure ceramic or silicon thermal interface material. The fluorescent material may comprise a Lumiramic material, characterized by an efficient and high light conversion, a high thermal conductivity, such as more than 6 W/mK at room temperature, a high thermal stability and/or highly scattering visible light. A fraction of the laser power dissipated in the fluorescent body may have a value equal to or more than 300 mW, preferably equal to or more than 800 mW, and more preferably equal to or more than 1.3 W.

[0024] Upon excitation with a single and/or with multiple laser pump beam(s) the fluorescent material is preferably characterized by a homogeneous radial emission at a different wavelength than the excitation wavelength, preferably in a plane perpendicular to the elongation direction of the fluorescent body. The transparent body may be thermally linked to a heat sink, for instance via heat pipes, via a heat conduction material or via a heat-spreader. The heat sink may be arranged on the opposite side of the collecting unit, which may be a reflector, such as a parabolic reflector or parabolic mirror, wherein the housing of the reflector may be used as a heat sink.

[0025] By scanning the fluorescent body with the optical radiation emitted by the source or by dynamically adjusting the scan area and/or the focus of the lamp spot, a dynamic tunable light spot can be achieved.

[0026] A focusing unit may be provided for bending and/or for scanning the light generated by the source. The lamp may be adjustable to excite fluorescent emission over various parts or lengths of the fluorescent material. Thereby, different beam shapes can be realized. The filament shaped Lumiramic emitter may comprise a plurality of segments, wherein each segment comprises a length of about 300 micrometers to 1 millimeter. In other words, a segmented luminescent body and/or a scanning laser beam are preferably used to realize a lamp adapted for generating a variable beam width. Therefore, while using a relatively simple mechanical setup different beam shapes adapted for different applications are realizable.

[0027] A segmented Lumiramic emitter arranged on an optical axis of a reflector comprising a parabolic shape, a Bezier type shape or any other shape may be used. The filament shaped Lumiramic emitter may comprise a plurality of segments, wherein the plurality of segments may be separated by a highly scattering material, such as titanium dioxide, adapted for preventing optical cross talk between the plurality of segments. These segments can be connected by melting glass, ceramic glue or other techniques. In this way damaging by high power density of a laser can be countervailed. Each segment of the plurality of segments may be excited individually which is adapted for emitting visible light by a blue or UV pump laser. The lamp according to invention may be arranged to emit white light.

[0028] The laser beam may illuminate four separate parts of a Lumiramic cylinder which leads to four different beam sizes. The total length and the diameter of the Lumiramic cylinder may correspond to 4 millimeters and 0.2 millimeter, respectively.

[0029] A scanning laser may comprise a scanning mirror or a stepping motor, respectively.

[0030] The concept of the invention is especially adapted for being used in automotive applications, especially for front lights, where high and low beams are required, respectively. With respect to that, especially swiveling beams and "side-looking" light in case of turning left or right can be accomplished, too.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

[0032] In the drawings:

Fig. 1 shows a laser pumped lamp according to an embodiment of the invention;
Fig. 2 shows a lamp comprising two pump lasers according to an embodiment of the invention;
Fig. 3 schematically illustrates an elongated filament according to an embodiment of the invention;
Fig. 4 shows isotropic phosphor density and also gradually increasing phosphor density in the fluorescent body according to an embodiment of the invention;
Fig. 5 shows different possibilities of encapsulating the fluorescent body into the transparent body according to an embodiment of the invention;
Fig. 6 shows a lamp comprising a transparent body which essentially fills up the entire space between the fluorescent body and the collecting unit according to an embodiment of the invention;
Fig. 7 shows a laser pumped lamp comprising a small laser spot mode according to an embodiment of the invention;
Fig. 8 shows a laser pumped lamp comprising a broad laser spot mode according to an embodiment of the invention;
Fig. 9 shows a lamp comprising two pump lasers according to an embodiment of the invention; and
Fig. 10 shows a segmented Lumiramic emitter (right) arranged on an optical axis of a parabolic shaped reflector (left) according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0033] Fig. 1 schematically illustrates a laser pumped lamp 1 according to an embodiment of the invention. The lamp 1 generates radiation, i.e. light 2, and comprises a source having a laser 3. A fluorescent body 4 is substantially embedded in a transparent body 5 and provided away from the laser 3. The laser 3 is adapted for emitting optical radiation along an optical path and the transparent body 5 comprises the fluorescent body 4, wherein the transparent body 5 is arranged in the optical path. A collecting unit 8 is provided which is adapted for transmitting at least a portion of optical radiation emitted by the fluorescent body 4 to an output of the lamp 1. In this embodiment, the collecting unit 8 corresponds to a parabolic reflector. As can be seen from Fig. 1, the fluorescent body 4 has a shape that is elongated in a predetermined direction. In this embodiment, a focusing unit 6 is provided which is adapted for focusing the optical radiation 7 emitted from the laser 3 onto the fluorescent body 4. The focusing unit 6 may be adapted for focusing the radiation 7 through the transparent body 5. Furthermore, the transparent body 5 has a shape that is elongated into the same predetermined direction as the elongated shape of the fluorescent body 4. The collecting unit 8 comprises an optical center arranged in the transparent body 5. In this embodiment, the collecting unit 8 shows an optical center at a position where the fluorescent body 4 is provided. The collecting unit 8 is operable to emit radiation 2 coming from the fluorescent body 4 and irradiating through the transparent body 5 to an output of the lamp 1.

[0034] Fig. 2 schematically illustrates the lamp 1 comprising two pump lasers. The transparent body 5 has an optical transmission of more than 80 %. Furthermore, the transparent body 5 has a thermal conductivity of more than 10 W/mK. In this embodiment, the transparent body 5 and the fluorescent body 4 have a good thermal interface. In other words, the attachment between the fluorescent body 4 and the transparent body 5 has a low thermal contact resistance. This arrangement is obtainable by melting glass, ceramic glue, a transparent pressure ceramic or a silicon thermal interface material. The fluorescent material may also be sintered inside the transparent body 5. In other words, the transparent body 5 is a good thermal conductor since it acts as a heat-spreader.

[0035] Fig. 3 shows the transparent body 5 comprising the fluorescent body 4 according an embodiment of the invention. The material of the transparent body 5 comprises diamond. The fluorescent body 4 corresponds to a Lumiramic cylinder.

[0036] In an embodiment of the invention, preferably in lighting applications, the laser radiation has to be reshaped into a distribution required for a particular application.

[0037] In an embodiment of the invention, preferably in automotive front light applications, it is beneficial to realize a preserving system that utilizes the high brightness of the lamp 1.

[0038] Fig. 3 illustrates an elongated filament according to an embodiment of the invention. Fig. 3 also shows a connection to a heat-spreader 9 which is provided and is adapted for conducting the heat from the filament, in particular from the transparent body 5, to a heat sink. In other words, the transparent body 5 is thermally linked to a heat sink via the heat-spreader 9, wherein the heat-spreader 9 is being arranged on the opposite side of the collecting unit 8. In an embodiment of the invention, the housing of the collecting unit 8 is used as heat sink.

[0039] Fig. 4 illustrates the isotropic phosphor density in the fluorescent body 4 and also a gradually increasing phosphor density in the fluorescent body 4 according an embodiment of the invention. In this embodiment, the fluorescent body 4 comprises a material with a component resulting in a substantial light scattering inside the material. Upon excitation with a single or with multiple laser pump beam(s), the fluorescent material is further characterized by a substantially homogeneous radial emission in a plane perpendicular to the elongation direction of the fluorescent material at a wavelength different from the excitation wavelength. In this embodiment, the fraction of laser power dissipated into the fluorescent body 4 is larger than 300 mW. As shown in the first picture of Fig. 4, the phosphor density in the fluorescent body is distributed isotropically. The second picture of Fig. 4 shows that the phosphor density in the fluorescent body 4 is distributed with a gradient in density achieved in the elongation direction of the fluorescent body 4. Such a configuration is very suitable if the laser 3 is coupled in from the bottom side. The gradient may be realized in a way that the generated fluorescent radiation intensity follows substantially a linear function. In another embodiment, the generated fluorescent radiation intensity is constant. In another embodiment, there is a gradient in scattering of fluorescent material provided which increases in the direction of the laser beam emitted from the laser 3. This is realized by gradually increasing the concentration of titanium dioxide particles in the material. The third picture of Fig. 4 shows a gradient in density achieved in the radial direction of the fluorescent material comprising the highest density at the outer rim of the fluorescent body 4. Such a configuration is highly suitable, if the laser 3 is focused onto the fluorescent body 4 from the outside through the transparent body 5. In the embodiment illustrated in Fig. 4, the transparent body 5 is very close to the hot spot allowing a good heat transport. The fourth picture of Fig. 4 shows a gradient in density achieved in the radial direction of the fluorescent material comprising the highest density in the center of the fluorescent body 4.

[0040] In an embodiment of the invention, a dichroic coating is provided. The dichroic coating is provided on one side of the fluorescent body 4 to prevent light of a wavelength different from the excitation wavelength (i.e. the wavelength of the optical radiation provided by the laser 3) to pass back in the direction of the laser 3. The laser light, on the other hand, passes the dichroic coating which is provided on the lower side of the fluorescent body 4 as shown in Fig. 4. This is the side of the entrance of the laser beam. The use of a dichroic coating can generally be combined with any other embodiment of the invention.

[0041] Fig. 5 shows different examples of encapsulating the fluorescent body 4 into the transparent body 5 according to an embodiment of the invention.

[0042] Fig. 6 shows an embodiment of the invention wherein the transparent body 5 essentially fills up the space between the fluorescent body 4 and the collecting unit 8. In this embodiment, the shape of the transparent body 5 is not elongated. The reflection of light or radiation at a wavelength different from the excitation wavelength arranged at the collecting unit 8 is realized by total internal refraction (TIR). Alternatively, it may be realized by a reflector or by a dichroic coating. The latter is preferably capable to reflect visible light by IR radiation above 900 nm that is going to be transmitted. Alternatively, an extra lens behind the reflector and the rod is possible, too. In the embodiment illustrated in Fig. 6, the collecting unit 8 corresponds to a parabolic reflector adapted for collecting at least a part of the radiation and reflects the part of radiation into a predetermined direction.

[0043] Fig. 7, Fig. 8 and Fig. 9 show several embodiments of the invention.

[0044] Fig. 7 shows a laser pumped lamp 1 operating in a small laser spot mode resulting in a first predefined beam shape of the lamp 1. The beam shape corresponds to a narrow beam.

[0045] Fig. 8 illustrates the laser pumped lamp 1 operating in a broad laser spot mode resulting in a second predefined beam shape of the lamp 1. The beam shape corresponds to a wash beam.

[0046] Fig. 9 shows a lamp 1 comprising two pump lasers 3 and 3b, respectively.

[0047] The right part of Fig. 10 illustrates a segmented Lumiramic emitter arranged on an optical axis of a parabolic shaped reflector according to an embodiment of the invention. Alternatively, the shape of the reflector may be a Bezier type shape. The filament shaped Lumiramic emitter comprises a plurality of segments, each segment having a length of about 300 micrometers. The plurality of segments is separated by a highly scattering material such as titanium dioxide to prevent optical cross talk between the plurality of segments. Each segment of the plurality of segments is excited individually to emit visible light by a blue pump laser. The emitted visible light may be white light. For a parabolic shaped reflector geometry, as illustrated in the left part of Fig. 10, a beam shape calculation is performed. The calculation is based on the assumption that the segmented Lumiramic emitter is positioned on an optical axis of this reflector and that different segments are emitting. The right part in Fig. 10 shows the case that a laser beam illuminates four separate parts of a Lumiramic cylinder which leads to four different beam sizes. The total length and the diameter of the Lumiramic cylinder correspond to 4 millimeters and 0.2 millimeter, respectively. The left part in Fig. 10 shows the case for a scanning laser comprising a scanning mirror or a stepping motor, respectively. A lens on a rotating disc, i.e. a de-centered lens can be used, too.

[0048] It goes without saying that a homogeneous wide beam is realizable by the lamp according to the present invention. It is also possible that the laser beam is scanned or widened over the Lumiramic filament resulting in slight changes in the beam profile.

[0049] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive. The invention is not limited to the disclosed embodiments.

[0050] Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

Claims

1. A lamp (1) comprising:

   - a laser (3) adapted for emitting optical radiation along an optical path,
   - a transparent body (5) arranged in the optical path and comprising a fluorescent body (4), and
   - a collecting unit (8) adapted for transmitting at least a portion of optical radiation emitted by the fluorescent body (4) to an output of the lamp (1),

   wherein at least one of the transparent body (5) and the fluorescent body (4) has a shape that is elongated in a predetermined direction, and
   wherein the transparent body (5) has a thermal conductivity that is equal to or larger than 10 W/mK.

2. The lamp (1) according to claim 1, wherein each of the transparent body (5) and the fluorescent body (4) has a shape that is elongated in the same predetermined direction.

3. The lamp (1) according to any one of the preceding claims, further comprising a focusing unit (6) which is adapted for focusing the optical radiation emitted from the laser (3) onto at least a part of the fluorescent body (4).

4. The lamp (1) according to claim 3, wherein the laser (3) and/or the focusing unit (6) is arranged to scan the fluorescent body (4) with the optical radiation emitted by the laser (3).

5. The lamp (1) according to any one of the preceding claims, further comprising a heat-spreader (9) provided at the transparent body (5), wherein the heat-spreader (9) is adapted for conducting heat irradiated from the fluorescent body (4) to a sink.

6. The lamp (1) according to any one of the preceding claims, wherein the transparent body (5) has an optical transmission equal to or more than 80 %.

7. The lamp (1) according to any one of the preceding claims, wherein the transparent body (5) is a holder, and wherein the holder has a wall thickness equal to more than 0.5 millimeter and/or equal to or less than 10 millimeters.

8. The lamp (1) according to any one of the preceding claims, wherein the transparent body (5) comprises a material chosen from the group consisting of diamond, sapphire, and a ceramic material.

9. The lamp (1) according to any one of the preceding claims, wherein the transparent body (5) has a shape that corresponds to a rod, a fiber and/or a cylinder.

10. The lamp (1) according to claim 9, wherein the rod has a diameter equal to or more than 1 millimeter and/or equal to or less than 10 millimeters, and wherein the rod has a length equal to or more than 0.3 millimeter and/or equal to or less than 100 millimeters.

11. The lamp (1) according to any one of claims 9 and 10, wherein the rod corresponds to a thin elongated Lumiramic material.

12. The lamp (1) according to any one of the preceding claims, wherein the fluorescent body (4) comprises a fluorescent material that comprises a predetermined diameter and a length of equal to or more than 3 times the predetermined diameter.

13. The lamp (1) according to claim 12, wherein the fluorescent material comprises a Lumiramic material.

14. The lamp (1) according to any of the preceding claims, wherein a dichroic coating is provided on a side of the fluorescent body (4), the dichroic coating being arranged to pass the optical radiation emitted by the laser (3) while preventing light of a different wavelength to pass back in the direction of the laser (3).

15. An automotive front light comprising the lamp (1) according to any one of the preceding claims.

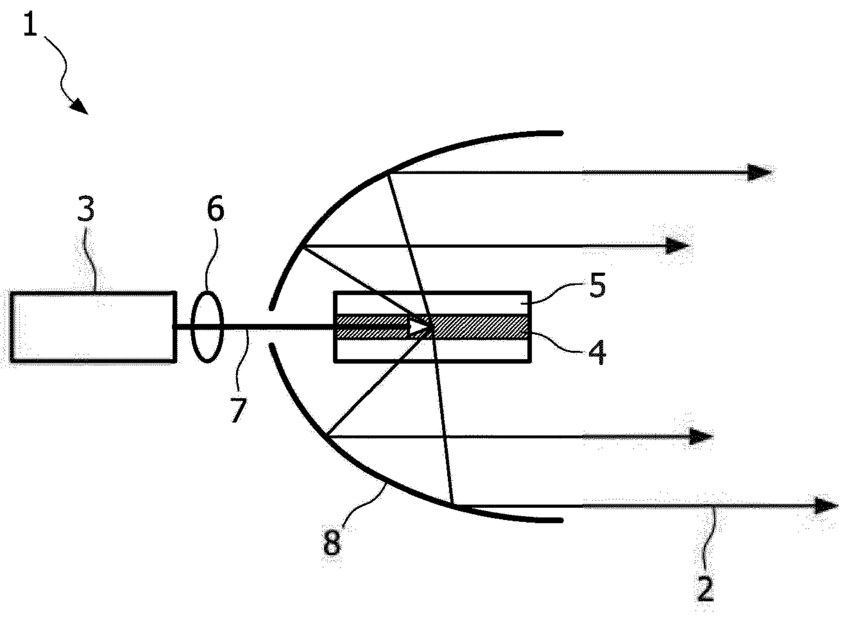

FIG. 1

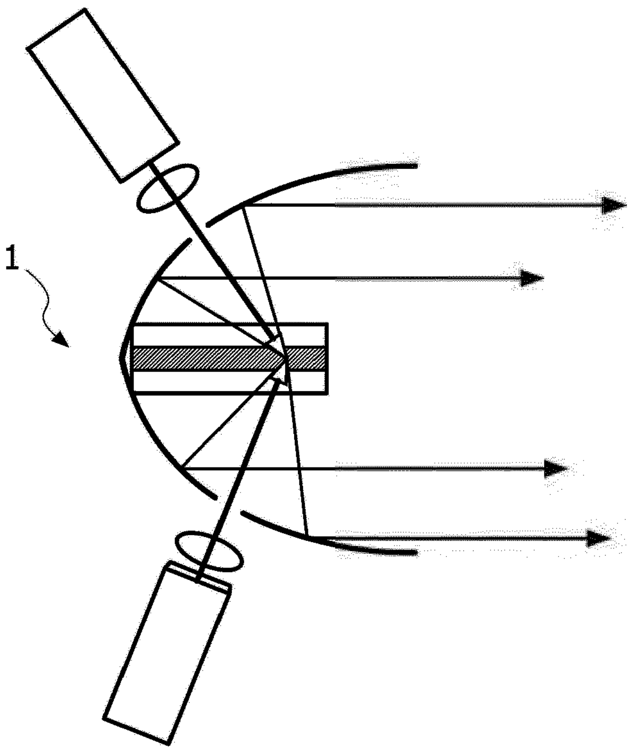

FIG. 2

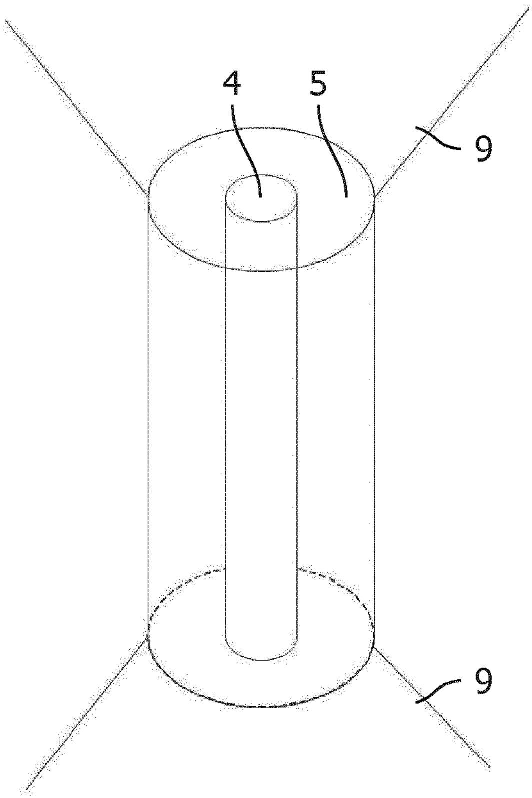

FIG. 3

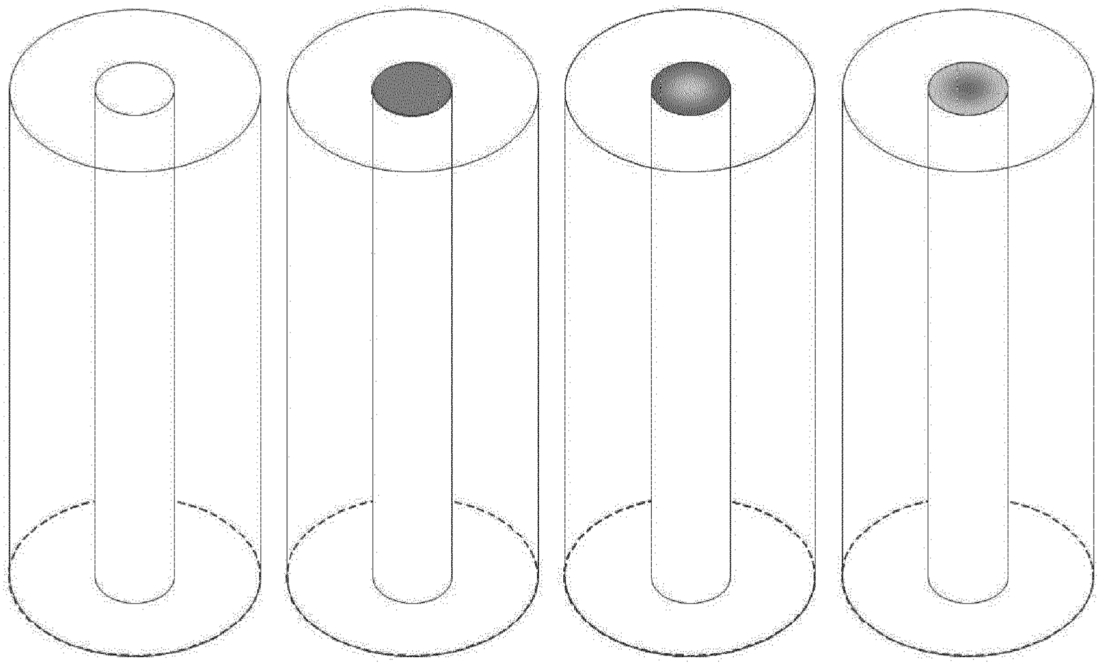

FIG. 4

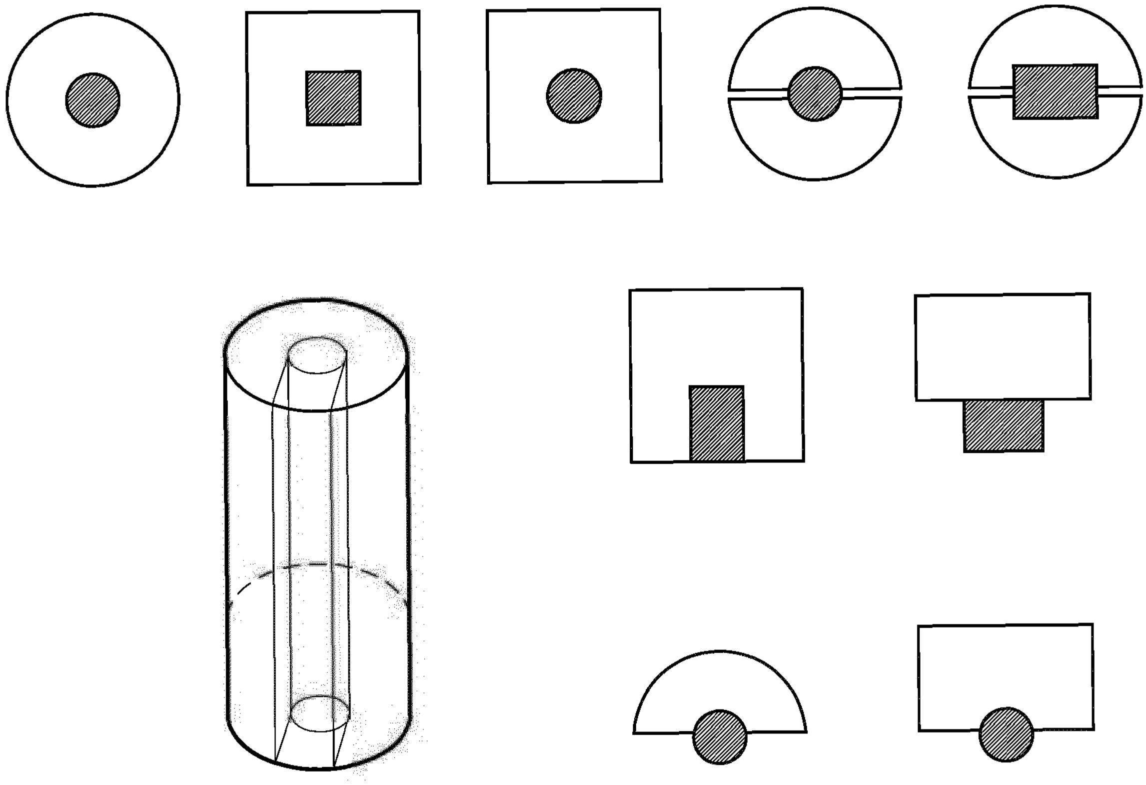

FIG. 5

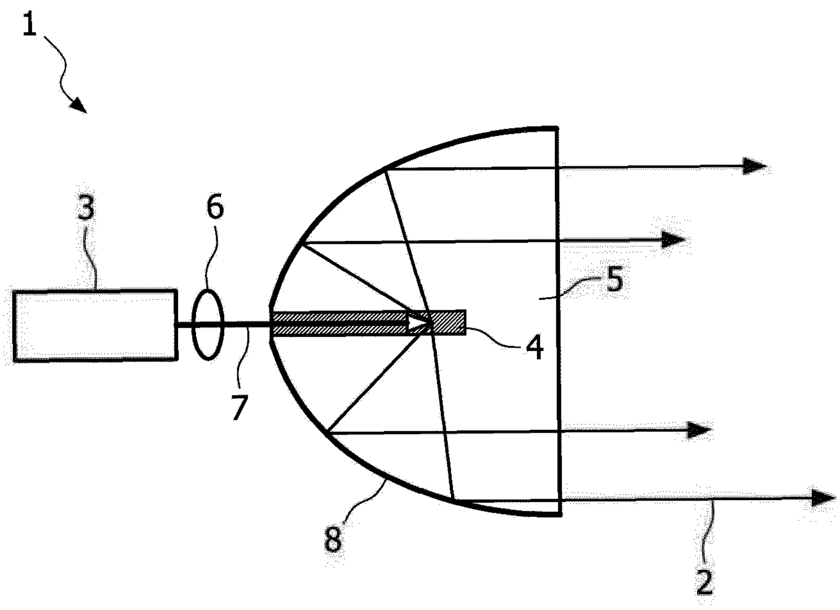

FIG. 6

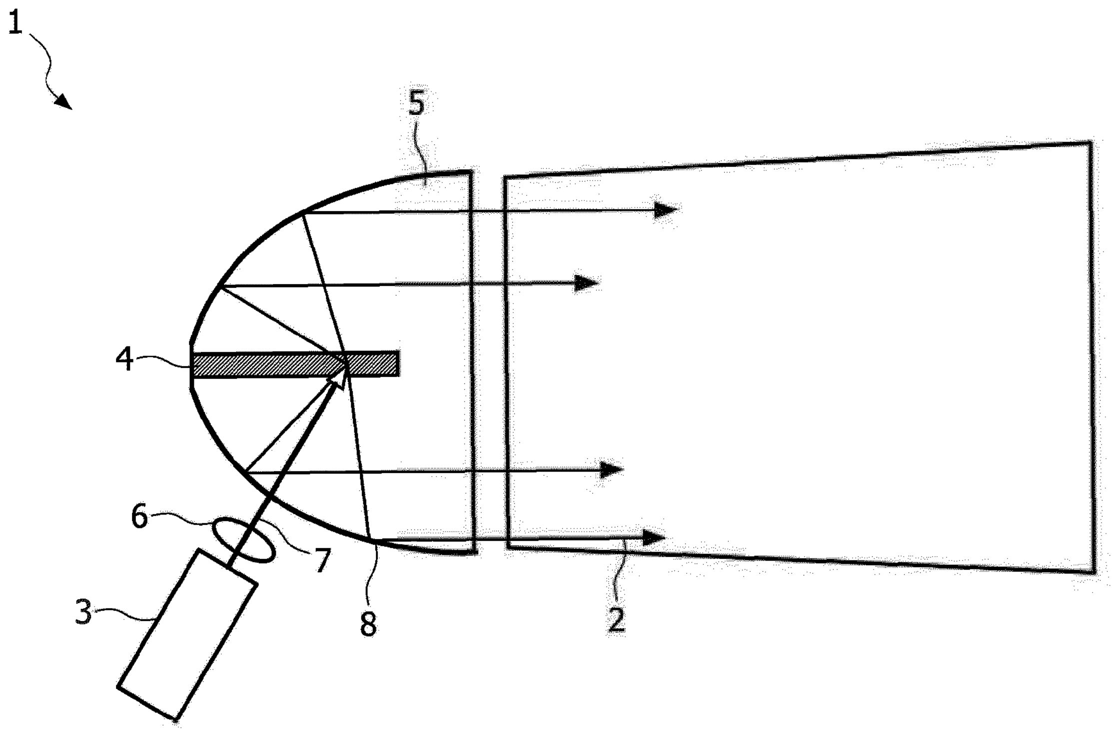

FIG. 7

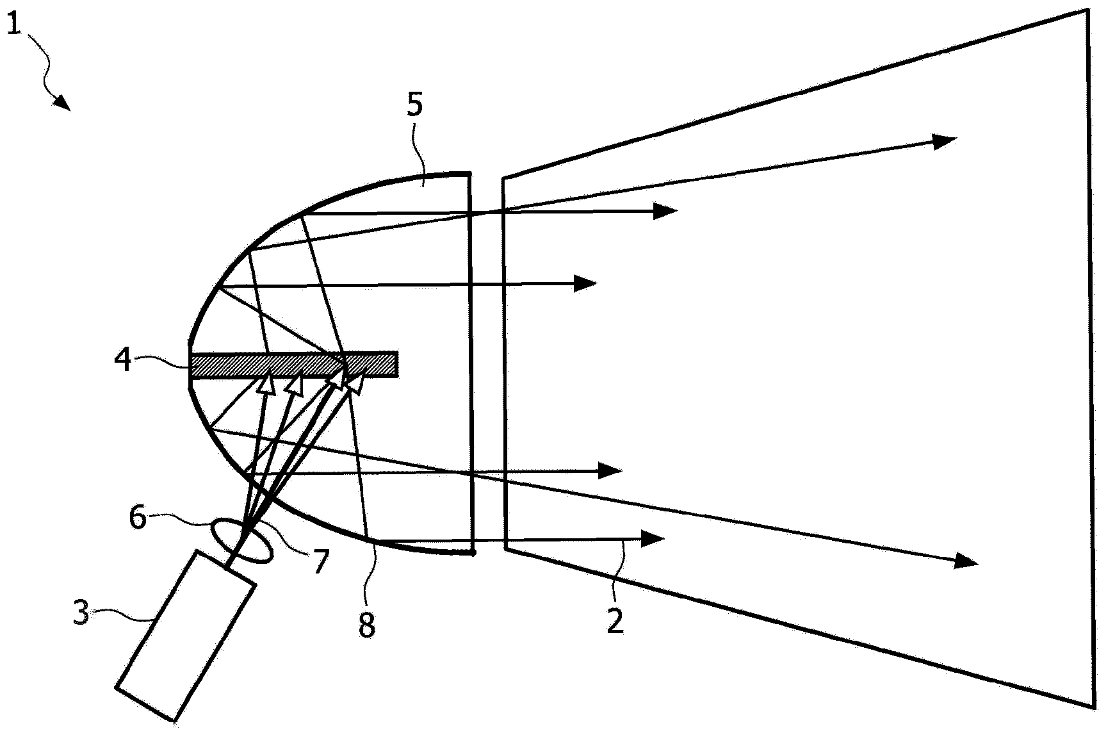

FIG. 8

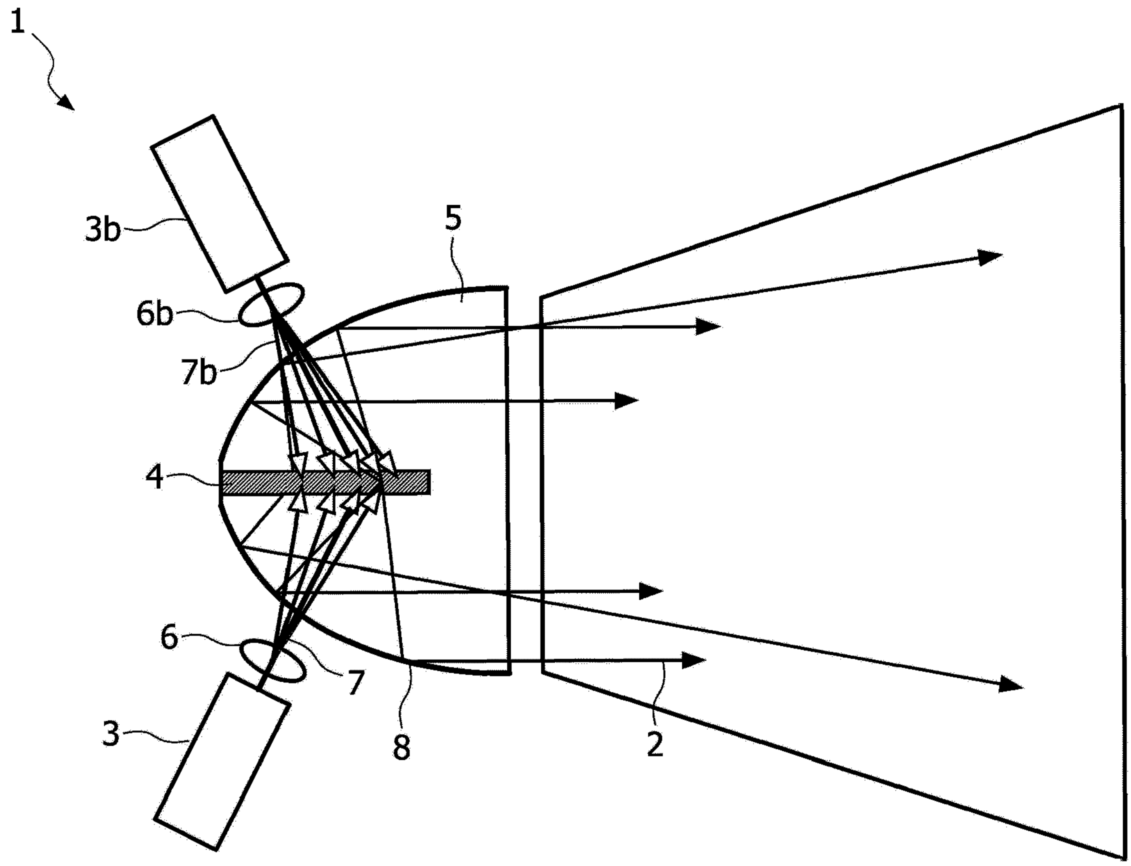

FIG. 9

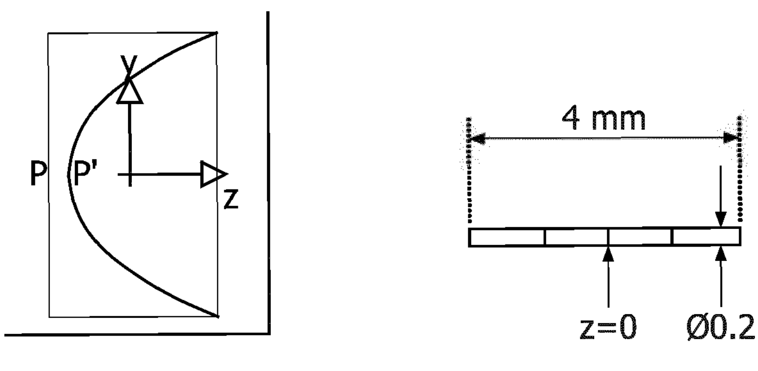

FIG. 10

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EUROPEAN SEARCH REPORT

Application Number
EP 18 21 2832

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	EP 1 734 302 A1 (NICHIA CORP [JP]) 20 December 2006 (2006-12-20) * figure 7z * -----	1-15	INV. C09K11/08 G02B6/00 H01L33/50
Y	WO 01/40702 A1 (CREE LIGHTING CO [US]) 7 June 2001 (2001-06-07) * figure 1 * -----	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

C09K
F21S
G02B
H01L

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	2 April 2019	Quertemont, Eric

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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E : earlier patent document, but published on, or after the filing date
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 21 2832

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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02-04-2019

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